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The Progress of Metabolism after Food in Swine.

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(From the Institute of Animal Nutrition, Cambridge.)

The results described in the present paper have emerged in the early stages of what is intended to be a comprehensive investigation of the course of metabolism in swine when age, weight, food, temperature of surroundings, etc., vary.

Measurements have been made of the heat evolution of a fasting hog at various stages of fasting up to a maximum of six days, and at various temperatures ranging from 10° C. to 20° C., by means of the calorimeter described by one of the writers (J. W. C.) in the 'Journal of Agricultural Science' for October, 1921.

The hog used has been the same throughout—a pedigree large white, bred by Mr. K. J. J. MacKenzie at the University Farm. The animal was a male which had been castrated at the age of 9 weeks. When the observations began on November 28th, 1921, his age was 10 months and he weighed

220 lb. At the conclusion, on March 22nd, 1922, he weighed 342 lb. This works out at an increase in live weight of 122 lb. in 114 days, which is sufficient evidence that his occasional fasts had not affected his well-being.

After each period of 4 to 6 days' fasting he was given a rest for about a fortnight before he entered the calorimeter again. His food in the intervals between the fasts has varied a little in composition, but has been of the same general character. The total amount per day has been increased from time to time, so as to be roughly proportional to the two-thirds power of his weight.

As a general indication of the nature and amount of his food, he received the following daily ration when he weighed 300 lb.: 2 lb. sharps, 2 lb. barley-meal, $1\frac{1}{2}$ lb. bean-meal, 1 lb. maize-meal, 1 lb. fish-meal.

In severe weather the hog was kept in a sty in the laboratory in the intervals between the fasting periods. More generally he was kept in a small paddock with a wattle shelter. He stripped the paddock quite bare of vegetation at an early stage, but was given a little green food daily.

When in the calorimeter he was kept in darkness throughout the fasting period to encourage him to sleep. He received 2 gallons of water daily, introduced through a pipe from outside. The ventilation air was adjusted to about 450 litres per minute, which proved to be enough to keep the interior of the calorimeter fresh and the hog in good condition.

No measurements were made of the respiratory exchange nor of the nitrogen excretion. The method of measuring the heat evolution is fully described in the paper mentioned above, and need not be repeated here in any detail. It is sufficient to say that water kept at a constant temperature by a thermostat circulates round the calorimeter, and the quantity of heat carried off is calculated from the rate of flow of the water and the difference of temperature between the inlet and the outlet.

Additions are made for the latent heat of the water vapour brought away by the ventilating air, for the sensible heat in the ventilating air, and for leakage through the calorimeter walls.

The difference of temperature between the inlet and outlet water is measured by a thermoelectric couple and a Cambridge and Paul thread recorder, which traces out a continuous record of the amount of heat taken up by the water.

This method of recording the temperature difference has the great advantage of enabling the observer to judge from the curve traced out whether the hog has been asleep for a sufficiently long time to permit of observation of the metabolism uncomplicated by the effect of muscular movements. The curve shows every movement of the hog, even though slight.

It also gives warning if there is a failure in any part of the apparatus. Preliminary tests were made by direct observation of the hog and of the various appliances to find what disturbance of the curve resulted from the various possible causes, and after a little experience an observer watching the galvanometer record can feel the pulse of the whole apparatus. If anything goes wrong, he can judge with fair certainty of the nature of the lapse. Such lapses are now rare and the weak points are being gradually eliminated.

The hog is very regular in his habits when in the calorimeter. He wakes between 6 and 8 in the morning. During the day he seldom sleeps, but keeps in constant motion, and the curve shows pronounced hills and valleys, the general level usually rising gradually until the end of the afternoon, when it is much higher than it was during the preceding night. The hog's time for falling asleep rarely varies from 5.30 P.M. by more than half an hour in either direction, and from that time he sleeps until the next morning—often without movement—except that in the early part of the night he rises for a short time to empty his bladder.

As he has grown older and heavier, however, this regularity has become less marked. He is also much less tractable than when he was younger. It is more difficult to get him into and out of the calorimeter, and the excitement of entering takes longer to subside. There is also some indication that the higher temperatures lead to greater restlessness.

Fig. 1 is the galvanometer curve obtained on the fifth day of the fasting period, which began on November 28th. The temperature of the inlet water was 13·3° C. It is chosen as showing the characteristic features of these curves.

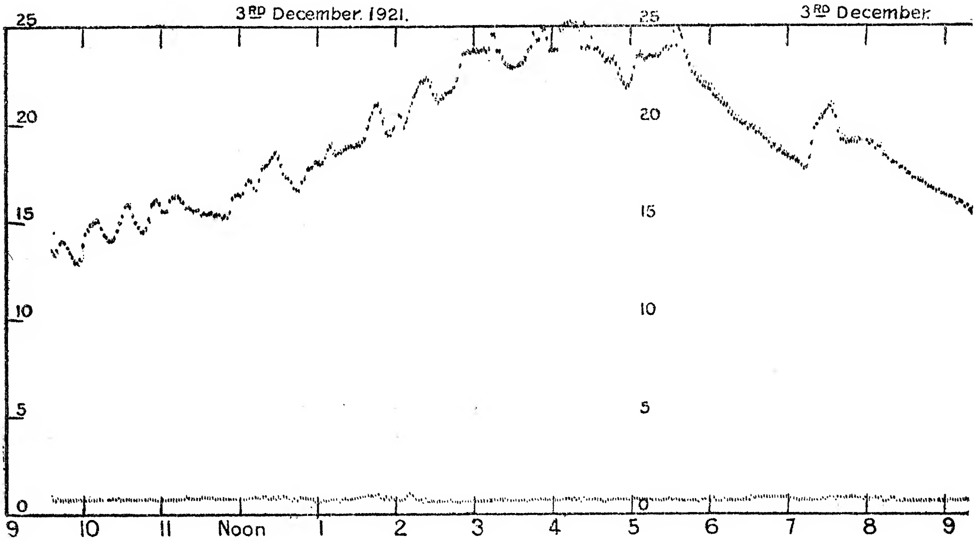
Notice the irregular and large rise in the metabolism during the daytime of December 3rd. The hog went to sleep at 5.30 and the curve at once began to fall rapidly. At 7.15 he rose and emptied his bladder. The special shape of the hump—a rapid rise followed by a rapid fall interrupted by a horizontal piece or a gentle rise—is characteristic of urination. Presumably the rapid rise is due to the warm urine falling on the floor of the calorimeter. The heat in the urine is quickly taken up by the circulating water, and the curve falls again, but before the fall has gone far the increased metabolism of the hog due to his movement begins to show itself and the fall is checked.

The hump shortly after 10 was due to a brief lapse in the thermostat. Such lapses are rare. They are characterised by a rapid rise (or fall), followed by a rapid fall (or rise) to the normal.

It is clear that readings during the day are impossible if it is desired to exclude the effects of muscular movements on the metabolism. Further, the increased metabolism caused by the day's activity takes many hours to subside, so that readings can as a rule be taken only in the early hours o the morning. This makes the work trying for the observer, but it seems to be inevitable—at least in the case of this particular hog.

The steady fall in the curve through the night is not due solely to the subsidence of the effects of muscular activity. The time taken to reach a steady state is prolonged by the heat capacity of the apparatus, which causes a lag in the readings. The calorimeter used in the present experiments has a water equivalent of 85 litres. It is constructed in such a way as to give prompt indications of changes of heat output, but is not suited for the measurement of rapid changes.

It is also to be remembered that the body temperature of the hog is probably falling through the night, which gives rise to a drop in the curve.



The body temperature in man is known to reach a steady minimum in the early hours of the morning, and as almost all the observations were made between 3 A.M. and 6 A.M. the effect of changes of body temperature is probably to a great extent eliminated.

The present paper is concerned with a feature which has been observed in the variation of the resting metabolism in the course of each experiment.

Six experiments, ranging from four to six days of fasting in each, are included in the work under consideration. The temperature of the circulating water when it entered the calorimeter varied from 10·3° to 20·4° C. in the various periods. In any one period it was maintained constant by a thermostat.

Readings of the various instruments were taken at hourly, or sometimes at half-hourly, intervals, when the galvanometer curve showed that the hog was asleep, and had been asleep for a sufficiently long time for the curve to have become steady. At the conclusion of the experiment, the curve and the records of the readings were carefully studied, to find the times at which the metabolism was at a steady minimum. Usually, only one such point was selected in each night—very occasionally no point was judged to be good enough. Any possible bias in the selection of the points is excluded by the length and intricacy of the calculation, which depends on so many readings that it is impossible to predict the result before it is actually reached.

It should be noted that the results tabulated below are not the total heat evolution over definite periods, but the rate of evolution at selected moments.

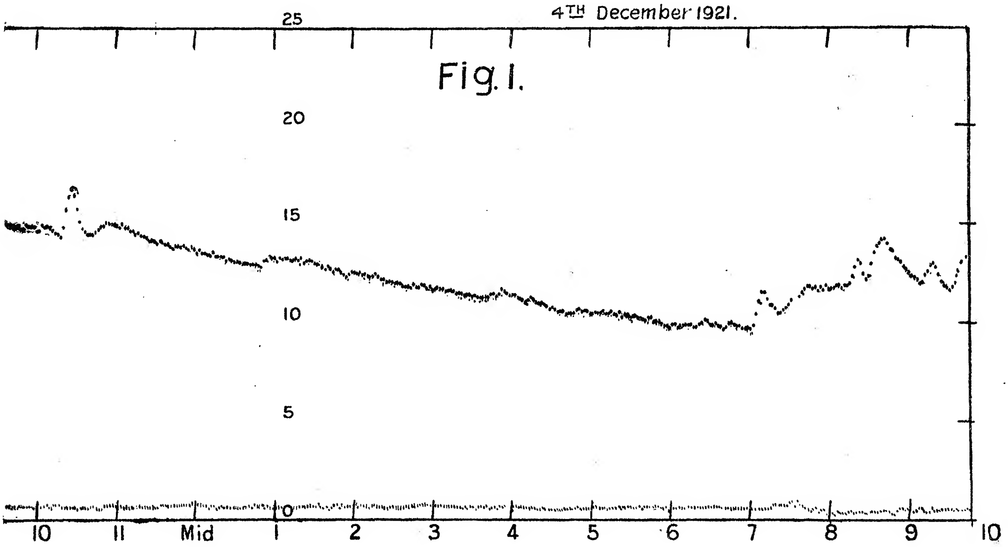


Table I gives a summary of all the measurements that have been made up to the present. The results have been calculated to four significant figures to avoid an accumulation of errors, but it cannot be claimed that the fourth figure has much meaning.

The metabolism is given in kilogramme-calories per minute. The date is that on which the hog was taken out of the calorimeter. The time is given in hours since the last meal. Before the figures can be used for their ultimate purpose of investigating the effect of temperature on basal metabolism, they must be corrected for the weight and age of the hog. For the purpose of the present paper the correction is not needed, and they are given as they were calculated from the observations.

It should be mentioned that the first measurement in each set has less

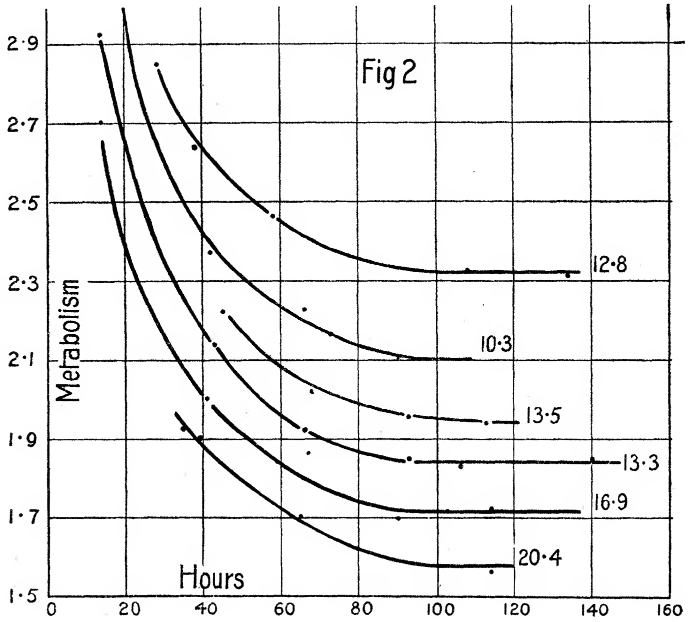
Table I.

Date…………	Jan. 8.	Date…………	Dec. 4.	Date…………	Feb. 25.
Weight ……	252 lbs.	Weight ……	216 lbs.	Weight ……	306 lbs.
Temperature	10·3° C.	Temperature	13·3° C.	Temperature	13·5° C.
Time.	Metabolism.	Time.	Metabolism.	Time.	Metabolism.
19	3·188	14	2·927	45	2·221
42	2·374	43	2·139	68	2·019
66	2·227	66	1·926	93	1·955
90	2·105	93	1·852	113	1·936
		116	1·833		
		140	1·851		
Date…………	Dec. 19.	Date ………	Feb. 5.	Date ………	March 22.
Weight ……	231 lbs.	Weight ……	293 lbs.	Weight ……	342 lbs.
Temperature	16·9° C.	Temperature	20·4° C.	Temperature	12·8° C.
Time.	Metabolism.	Time.	Metabolism.	Time.	Metabolism.
14	2·703	35	1·927	28	2·647
41	2·058	39	1·904	38	2·438
67	1·869	65	1·702	58	2·266
90	1·702	114	1·562	108	2·126
114	1·725			134	2·115

weight than the rest. It was made in some cases before the hog had completely settled down after entering the calorimeter. He was usually put in at about 10 A.M., and was given his last meal as soon as he entered. During the first day his behaviour varied very much. Sometimes he slept for a great part of the day, at other times he was restless, and his metabolism mounted very high. Speaking generally, he did not settle down to his regular habits until the second night, and therefore the earliest readings are liable to be a little irregular. Nevertheless, they give a fairly good guide as to the general trend of metabolism in the early stages of the fasting period.

There was a mishap in the period at 20·4° C., which renders the whole of the observations in this period unsatisfactory. The metabolism, calculated after 35, 39 and 65 hours' fasting, proved to be about double what was expected. After much investigation of possible causes, it was found that, by an oversight, a current had been left running in a resistance wire inside the calorimeter, thus introducing heat additional to that given out by the hog. The current was read on the ammeter, and a correction made for the heat introduced by it, but the correction is somewhat doubtful, as it is not certain that the current had been quite constant during the time it was running. The observations at 35, 39 and 65 hours are affected by this correction. The observation at 114 hours was made after the current had been stopped for a sufficiently long time to allow the temperature of the calorimeter to settle down to what it should have been throughout the period.

Fig. 2 shows the result of plotting all the observations on a single sheet.



The ordinates are the metabolism in kilogramme-calories per minute, and the abscissæ are the hours elapsed since the last meal.

The separate curves are identified by the temperatures written against each, this being the temperature of the inlet water, and therefore the approximate temperature of the interior of the calorimeter. The difference of temperature between the inlet and outlet water was small, seldom exceeding half a degree.

The curve marked 12·8° is raised 0·2 calories in the figure, in order to keep it clear of the 10·3° curve.

The very small divergences of the points from smooth curves appears to justify the writers in believing that they have made some advance in the accuracy of measurement of resting metabolism. Only one spot is conspicuously discordant—the spot at 67 hours on the 16·9° curve. The galvanometer curve was in this case less smooth than usual, and suggested that the hog, though asleep, may not have been perfectly still. Another spot—that at 66 hours on the 10·3° curve—is about 0·025 cals. above the curve. It should be noted that these two, the only really discordant spots, are both high. Instrumental errors might be expected to be indifferently high or low. Anomalous readings due to the hog would be almost certainly high.

Tangl* states that the swine with which he worked reached their basal metabolism after three days' fasting. The hog with which the present writers have worked clearly does not reach his basal metabolism until after four days. There is in every case an appreciable fall after the third day.

It might be noted in passing, that if the metabolism had been measured throughout the whole time of fasting, the curve obtained would touch the curves of fig. 2 only for a brief period in each day. Between these points of contact there would be large irregular excrescences due mainly to muscular activity. The fact that the metabolism constantly returns to the regular curves of fig. 2 gives support to the view that the extra metabolism arising from exercise has different characteristics from that due to the recent taking of food.

It will be seen from fig. 2 that the curves show a striking parallelism. The extent to which they are really parallel is easily tested by superposing them on each other.

There are two methods by which they can be brought together. One is by altering all the ordinates of any one curve by the same constant amount, that is, by sliding each curve up or down bodily until the curves come together as nearly as possible. The other method is by increasing or diminishing all the ordinates of any one curve in the same proportion. In the present case the first of these is clearly the better. The curves are not merely of the same general character, but, judged by the eye, are the same curve in different positions. Proportional movement would flatten the higher curves more than the lower and lessen the appearance of parallelism. Both methods have been tried, and it has been found that bodily movement of the curves does in fact give rather better concordance.

Independently of this, there appears to be some reason for expecting a more intelligible result if we adopt the method of bodily transference. The actual metabolism at any moment may be taken as the basal metabolism *plus* the increased metabolism, if any, resulting from the food taken before the fast began. If, then, any one curve be moved down by the amount of the basal metabolism corresponding to the temperature, age, weight of hog, etc., at which the curve was made, a curve will result whose ordinates show the diminishing effect of the food, separated from the metabolism which must go on so long as the animal lives, whether he is fed or not. It will be seen presently that such a curve leads to interesting conclusions.

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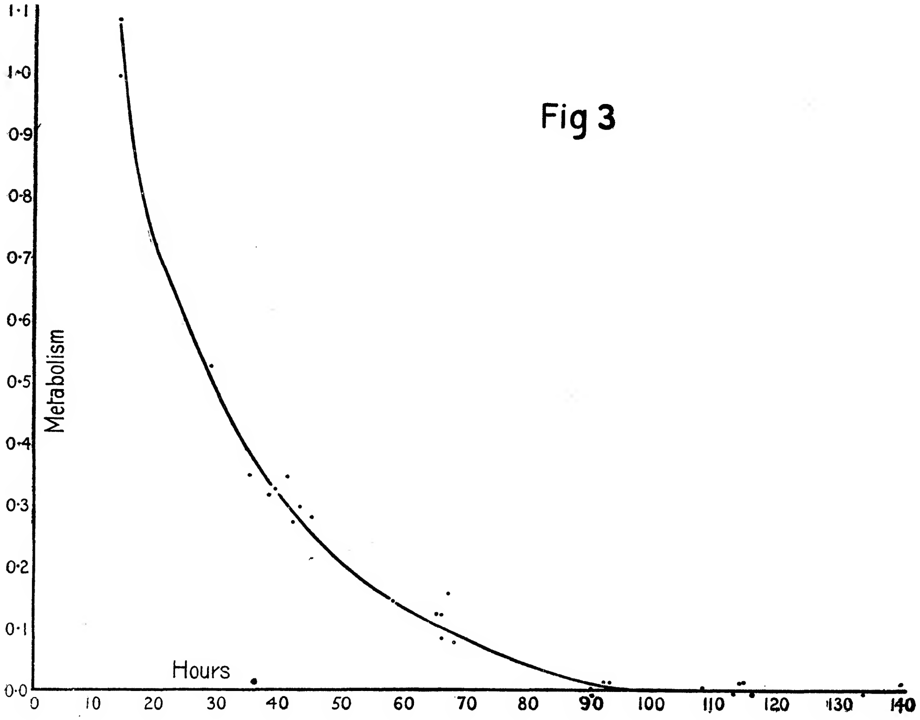
* 'Biochem. Zeit.,' 44.

Fig. 3 gives in effect the result of moving all the curves so that the horizontal part at the right-hand end of each coincides with the axis of the abscissæ. The curve was constructed in the following way.



The basal metabolism for any one fasting period was determined from the corresponding curve in fig. 2. Each of the measurements in Table I, from which this curve was constructed, was then reduced by the amount of the basal metabolism and the residues plotted at the appropriate times in fig. 3.

The same procedure was adopted with all the curves.

Lastly, a curve—which we may call a composite curve—was drawn through the spots so obtained. The degree of concordance of the original component curves, as regards their shape, can be judged by the extent to which the spots lie on or near the composite curve.

It will be seen that the divergence of the spots from the composite curve is small. Even though the apparatus were perfect we could not expect the spots to be perfectly consistent, for the hog cannot be assumed to have been in precisely the same state of vigour throughout the experiments, which, it must be remembered, extended over nearly 4 months.

The concordance is such as to justify us in concluding that to a very considerable degree of approximation the curves are identical.

It is worth noting that the composite curve is nearly the same as that marked 13·3° in fig. 2. The measurements from which the 13·3° curve was plotted were made in specially favourable circumstances. The apparatus worked well throughout the 6 days covered by the experiments, the hog was regular in his habits and the external temperature changed little. The 13·3° experiment was certainly the best of the series, as can be seen in fig. 2 by the closeness with which the curve follows the spots, and it is satisfactory to find that this curve is practically the mean of the whole of the curves.

When we consider the very considerable variation in the age and weight of the pig during the time over which the experiments extended and the range of temperatures of the different periods, it appears that we may conclude that the rate of change of the resting metabolism at any moment depends only on the time elapsed since the last meal, and is independent of the age and weight of the hog and of the temperature of his surroundings, though as will be shown later the increase in weight is perhaps not such as would be expected to affect the metabolism very greatly.

One other reservation must also be made. In the course of the 4 months covered by the work the hog's food was of the same general character and was increased gradually so as to be roughly proportional to the two-thirds power of his weight, that is to say, to the area of his surface. It is possible that if the food had been varied in kind from time to time, and the quantity had not been regulated to keep pace with the hog's growth, the consistency of the observations would not have been so good.

The writers intend to investigate later the effect of variations in feeding on the trend of the metabolism. It is not unlikely that the equation to be deduced presently from the curve will fit in all cases, but the constants of the equation may be found to depend on the kind of food given.

It appears then that in the circumstances of the experiments the resting metabolism follows a course which is constant. The curve may, therefore, be expected to express some physiological law, and to find that law the first and most obvious course is to attempt to find some equation that will fit the curve.

We shall show that the ordinary exponential equation $y = \epsilon^{c-kt}$ or, as it may be written, $\log y + kt = c$, where y is the metabolism at time t, fits the curve to a high degree of approximation. This equation is familiar to chemists and physicists as it expresses the fact that a substance is disappearing at a rate which is proportional to the amount of that substance which is still unchanged. It is in particular the expression of the fundamental form of Guldberg and Waage's Law of Mass Action.

The applicability of the exponential equation was tested in the following way:—The curve as shown in fig. 3 was drawn on a large scale, the greatest care being taken to make it the best possible expression of the data. The ordinates were then measured at every 10 hours from 20 to 70 hours after the last meal. The times selected were not taken very near either the beginning or end of the curve. In the former case the shape of the curve is uncertain for reasons given above, and the curve is so steep that a small change in its shape makes a great change in the height of the ordinate at any point, whilst near the right-hand end of the curve the ordinates are too short to measure accurately. We have then the data shown in Table II.

Table II.

Time (t).	Metabolism (y).	Log y.	c.
20	720	2·857	3·224
30	480	2·681	3·232
40	312	2·494	3·228
50	204	2·310	3·227
60	135	2·130	3·231
70	87	1·940	3·224

The metabolism is given in gram-calories to avoid the inconvenience of negative logarithms. The meaning of the fourth column is explained below.

We have next to find whether such a value of k can be determined as will give the same value to $\log y + kt$ with any pair of corresponding values of $\log y$ and t from Table II.

The best value of k is found by the method of least squares from the pair of simultaneous equations

$$\left.\begin{aligned}\Sigma(\log y) + k\Sigma(t) &= nc\\ \Sigma(t\log y) + k\Sigma(t^2) &= c\Sigma(t)\end{aligned}\right\}.$$

The calculation of k from these equations need not be given here. The result is $k = 0·01835$.

We now calculate the value of $\log y + kt$—that is c—from each pair of values of $\log y$ and t in Table II, using the value of k just found, and so get the six independent values of c shown in the fourth column. The extent to which these values of c diverge from their mean is a criterion of the fitness of the logarithmic equation to represent the curve.

It will be seen that the extreme range from the smallest to the largest is only about 1 part in 400. This very close agreement is better than could have been expected and is no doubt partly due to a fortunate accident in the drawing of the curve, though this has had no great effect on the result, for the whole process of spotting the points, drawing the curve and calculating the results has been carried out independently three times. The slight differences in the three curves made an appreciable difference in the value of k and a small difference in the mean value of c, but in each of the three cases the agreement between the various values of c was very good. It may, therefore, be concluded that the assumed equation represents the curve to a high degree of approximation.

It should be mentioned here that the family of hyperbolic curves whose general formula is $y^n(t+a) = c$ have the same general shape as the curve of fig. 3, and it seemed possible that some member of the family might fit the curve. Theoretically any three pairs of values of y and t would enable us to find a, c and n, but in practice the equation is very intractable. An exact determination of a, c and n is not possible. The best that can be done is to make a series of successive approximations. The equation has been tested by one of the writers (J. W. C.) by a method of approximation, and he has convinced himself that it cannot be made to fit the curve with anything approaching the accuracy of the logarithmic curve.

We have now found an equation which shows how the metabolism varies with the time elapsed since the last meal. We can go a step farther and find how this metabolism is related to the amount of metabolisable substance in the organism.

We have as the data from which to find this relation the two equations—

$$\log y + kt = c, \tag{1}$$

$$y = -k'(dq/dt). \tag{2}$$

The equation (1) is the relation which has been established experimentally. Equation (2) is merely an analytical statement of the fact that the rate of change of the metabolisable substances is measured by the heat evolution, q being a variable which defines the amount of these substances still unchanged. It assumes, in fact, little if anything more than the doctrine of the Conservation of Energy.

We can write the second equation in the form

$$y\,dt + k'\,dq = 0$$

and differentiating the first equation gives

$$dt = -(1/ky)\,dy$$

whence $$-dy/k + k'\,dq = 0,$$

and integrating we have $$-y/k + k'q = p$$

where p is the constant of integration.

This may be written in the form

$$\frac{y}{q-c'} = \text{const.}$$

Thus we have the result that y is proportional to q, if q is measured from some constant value defined by c'. If the metabolisable substance is normally absent in inanition c' will be zero, for y and q will vanish together.

If the metabolisable substance is normally present in inanition, the analysis shows that it will reach a fixed minimum after a sufficient time has elapsed since the last meal. This minimum will be defined by c', and if q be taken as the excess above that minimum amount—just as y is taken as the excess above the basal metabolism—y will be proportional to q.

This is the Law of Mass Action, and we have the final conclusion that, with the reservation as to the possible effect of different varieties of food, the metabolism depends only on the time elapsed since the last meal, and is proportional to the amount of metabolisable substance still unchanged.

It is, of course, clear that the logarithmic equation cannot represent the metabolism completely back to the time when the hog took his last meal. If he had his meal at time 0 and then kept perfectly still, it is known that his metabolism would show little change for an hour or two, when it would rise rapidly to a maximum, remain there for a time depending on the nature of the meal, and then begin falling. Nevertheless it is of some interest to find what the equation gives for the metabolism at zero time.

Put $t = 0$ in the equation, and use the value of c given by the method of least squares—that is, the mean of the values in the fourth column of Table II.

We get $\log y_0 = 3{\cdot}228$ or $y = 1690$.

This is the excess of the actual metabolism over the basal. In order to get the actual metabolism at zero time for any given set of circumstances as regards weight, temperature, etc., we must add the basal metabolism for those circumstances. Take, for instance, the experiment at 12·8°. Divide 1690 by 1000 to reduce it to kilogram calories, and add 2·12 the basal metabolism of the 12·8° experiment, and we get 3·81 calories per minute.

For a few days before the beginning of the 12·8° fasting period, the hog lived in the calorimeter and was fed only once a day, in the evening, in the hope that he would settle to sleep quickly so that measurements might be made of his metabolism shortly after his meal. The attempt was not very successful. The values found in the first few hours after his meal ranged from 3·9 to 4·7 calories and did not fall on any regular curve. On no occasion did the animal really settle down until at least 12 to 14 hours after the meal, and seldom so early as that. The lowest value, 3·9, is probably less affected by muscular activity than the higher values, and is not greatly different from the value found from the equation.

Summary and Conclusions.

It has been shown that, to a high degree of approximation, the resting metabolism of a hog, during inanition, falls off in accordance with a curve which is the same over a wide range of weight and age of the hog and temperature of its surroundings. The drop from the metabolism measured at any given interval after the last meal to the basal metabolism is the same in every case, and it is therefore possible, by the use of the curve in fig. 3, to deduce the basal metabolism in any given circumstances from a single observation of the actual metabolism at any time.

The area enclosed between the curve of fig. 3, continued backwards to zero time and the two axes, is a measure of the heat given out between the last meal and the time of reaching the basal, when the heat corresponding to the basal metabolism is deducted, and the hog is assumed to have been at rest throughout the period. This amounts roughly to 3000 calories, and has been shown to be constant throughout the range covered by the experiments.

This constancy is difficult to understand, but it may perhaps be explained by the fact that the hog was 10 months old when the experiments began, and the increase in weight may have been almost entirely fat, which is to be regarded as inactive as regards metabolism. The hog has been measured from time to time. The measurement which is most easily made is his height from the ground to the highest point of his back. Near the beginning of the experiments this height was 32 inches and at the end it was 34 inches. The small increase in height is perhaps accounted for by a layer of fat, and it seems not improbable that the hog's active mass changed little during the experiments.

A smaller hog has now been procured and it is intended to find the shape of the curves over a much greater range of height and weight.

The excess of the resting metabolism above the basal metabolism has been shown to fall off according to the equation $\log y + kt = c$. This is the Law of Mass Action, which is of frequent occurrence in physical and chemical changes. In its strict form it means that a single monomolecular change is taking place and that the rate of change is proportional to the amount of unchanged substance. There are, however, other cases where a curve very nearly logarithmic would be obtained, and at this stage of the investigation it is unsafe to infer that the heat evolution is the result of a single monomolecular change.

It has not yet proved possible to make measurements of the resting metabolism very near the time of the last meal, and we cannot, therefore, exclude reactions with a high velocity coefficient which would give a metabolism of measurable amount only in the immediate neighbourhood of zero time.

Moreover, a large number of simultaneous reactions would compound approximately to a logarithmic curve, provided they were separately logarithmic, or very nearly so, and had velocity coefficients not diverging far from the mean. No doubt many vital processes do, in fact, proceed more or less in accordance with the logarithmic law, and it may be that the results obtained by the writers indicate merely that the velocity constants of the chemical changes concerned in the metabolism are not greatly different.

The work that has been done is plainly incomplete. The writers intend to pursue the investigation further—in the first instance in the directions already indicated. Such success as has been achieved in the experiments described above is in no small degree due to the care and skill of Captain J. S. Morgan, M.C., B.A., who has had entire charge of the hog and has kept him in perfect health throughout the work.

Electric Current as a Stimulus, with Respect to its Duration and Strength.

By Seichi Jinnaka and Ryotaro Azuma.

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Our experiments on the excitatory effect of an electric current have been carried out by examining the relation between the current-duration and its liminal strength. From the determination of the optimal electric stimuli of amphibian muscle and nerve by the condenser method (1) (2), and from the investigations on the relation of the current-duration to the liminal current-strength (3) (4), Keith Lucas confirmed that there should exist three substances, at least, in a normal sartorius muscle of frogs and toads; each substance being distinguished by its own "excitation time," that is, the substance α represents the muscle material, γ the intramuscular nerve material, and β the intermediary substance; the first showing the longest, the second the intermediate, the third the shortest "excitation time." His further investigations upon the excitatory process (5) (6), led him to confirm